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(54) Electro-optical receiver

(57) An electro-optical receiver uses a PIN photodiode 1 as a parametric amplifier to convert an incident light signal into a corresponding electrical signal. A locally generated frequency pump signal is applied 3,4 to the diode and part of its energy is transferred to the electrical signal whichis representative of the modulation of the incident light. The receiver exhibits very good linearity, and generates very little distortion or noise, but is capable of high sensitivity to low intensity light.

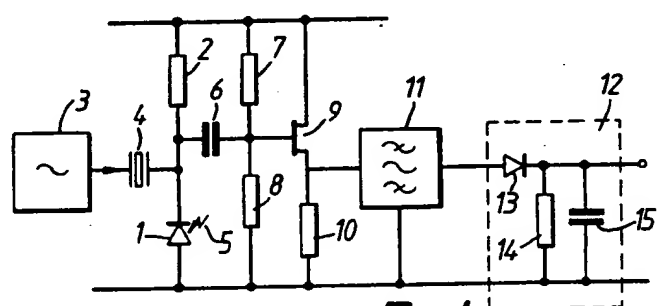

FIG. 1.

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The drawings originally filed were informal and the print here reproduced is taken from a later filed formal copy.

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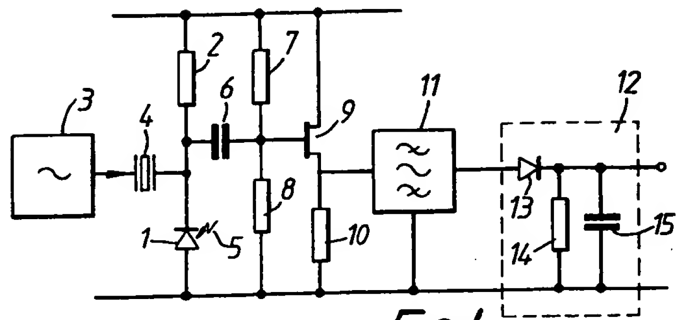

FIG.1.

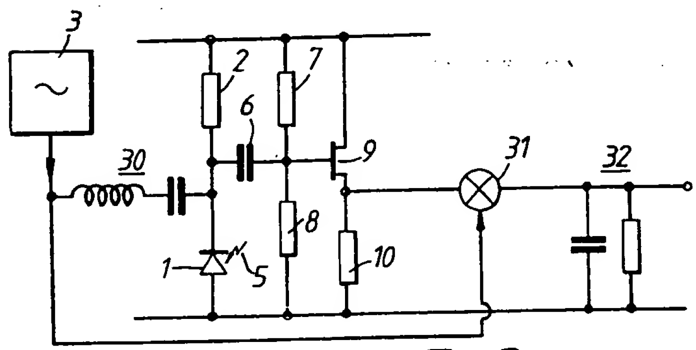

FIG.2.

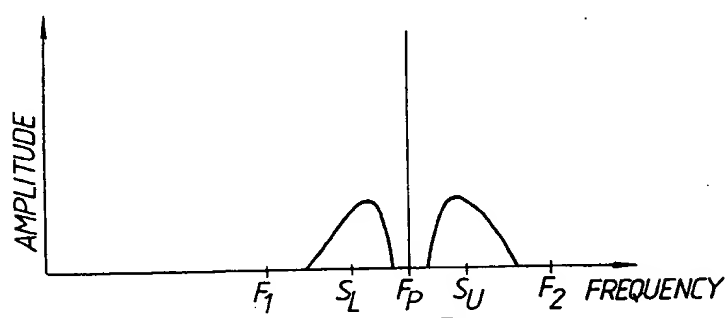

FIG.3.

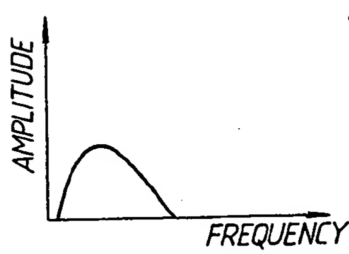

FIG.4.

SPECIFICATION

Electro-optical receiver

This invention relates to an electro-optical receiver which is operative to produce an output electrical signal in response to incident amplitude modulated light. The invention is particularly applicable to optical communication systems in which data or other information is conveyed by the amplitude modulation of light over possibly a considerable distance. If the level of the light which is received at the electro-optical receiver is low, as may well be the case if the light is transmitted over an appreciable distance via a light guide such as a thin glass fibre, it is difficult to generate an electrical signal at sufficiently high output level which faithfully reproduces the original optical modulation without the introduction of undesired distortion or noise. The present invention seeks to provide an improved electro-optical receiver.

According to this invention an electro-optical receiver includes a photo detector arranged to receive incident light; means for applying a narrow band pump signal to said photo detector to cause parametric amplification of the incident light; a demodulator; and a wideband impedance buffer having a high input impedance adapted to pass to the demodulator a composite signal comprising the narrow band pump signal and signals representative of amplitude modulation of the incident light which are arranged as upper and lower sidebands with respect to the pump signal.

Preferably the photodetector is a reverse biassed photo diode.

Parametric amplification by the photo diode enables power from the narrow band pump signal, to be transferred to the electrical signal produced by the photo diode and which is representative of the amplitude modulation of the incident light. As the intensity of the incident light may itself be at extremely low level, a degree of power amplification at the photodiode is very useful as the resulting electrical signal can then be passed to the demodulator without the need to involve an intermediate amplifying step which could introduce distortions, noise, or restrict the bandwidth of the modulation signal. As light is capable of carrying signals having a very large frequency bandwidth it is important to avoid the need to introduce frequency limiting filters into the signal path of the electro-optical receiver. By passing the composite signal through the impedance buffer in a form in which the signal representative of the received modulation constitutes upper and lower sidebands of the pump frequency, the original modulation signal is faithfully preserved and negligible distortion or noise is thereby introduced. The pump signal is removed at the demodulator which provides an output signal which may be regarded as being at baseband. To ensure that the frequency components of the pump signal do not overlap those of the wanted modulation signal, the pump signal has a narrow frequency bandwidth. Thus if the optical modulation is at a low frequency, i.e. of the order of a few kilohertz, then the pump signal is desirably a single tone derived from a crystal oscillator. On the other hand, if the modulation of the optical signal is at a wider band, then the frequency bandwidth of the pump signal may be correspondingly greater. The preferred method of implementing the demodulation will depend largely upon the frequency of the pump signal. Conveniently, the photodiode takes the form of a PIN diode as such a diode is particularly suitable for the purpose of parametric amplification, and suitable diodes of this kind are readily available.

The invention is further described by way of example, with reference to the accompanying drawings, in which:

Figure 1 illustrates an electro optical receiver which is suitable for receiving light which is amplitude modulated at a relatively low frequency,

Figure 2 which shows an electro optical receiver suitable for operation at higher frequencies, and

Figures 3 and 4 which are explanatory figures.

Referring to Fig. 1, an electro-optical receiver comprises a PIN photodiode 1 which is in series with a very high value bias resistor 2—in practice this resistor may not be needed. A signal operative at a frequency of 25 MHz is generated by a source 3 and fed via a very narrow band crystal filter 4 to the diode 1. As it supplies energy to the receiver this signal is termed a pump signal. The crystal filter 4 is very narrow band indeed so that in essence it transmits just a single tone at a frequency of 25 MHz. Amplitude modulated light which is incident upon the photo diode, as represented by the arrow 5, causes mixing of the pump frequency with amplitude modulation of the light to produce parametric amplification of the energy of the incident light. The pump signal causes modulation of the internal capacitance of the diode at the pump frequency which is at a higher frequency than that of the amplitude modulation of the incident light.

In this example, the incident light, which may originate from a remote source and be conducted to the pohotodiode 1 via an elongate glass fibre is of a non-coherent nature and is provided with a first continuous amplitude modulation of $2\frac{1}{2}$ MHz. This frequency of $2\frac{1}{2}$ MHz may be regarded as a carrier signal which in turn is frequency modulated by $\pm\frac{1}{2}$ MHz to constitute the data or information content of the received signal. Thus, the received signal consists of bursts of modulation occurring at 2 MHz or 3 MHz, the nature of this

modulation and its timing constituting the data itself.

The incident light produces a corresponding variation in the current passing through the PIN diode 1 and, by virtue of the parametric ampification of the diode, the energy of the incident light is amplified by transfer of energy from the pump signal to that of the modulation frequency. Thus the output of the photo diode 1 takes the form shown in Fig. 3 in which the pump signal is represented by the single frequency F_P and the electrical signal which is responsive to the received modulation is represented by the upper and lower sidebands S_U and S_L. This signal is fed via a d.c. blocking capacitor 6 to a pair of bias resistors 7 and 8 which are operative to bias the operating point of a wideband impedance buffer represented by a high frequency field effect transistor (FET) 9 having a very high input impedance. The transistor 9 is operative as a voltage follower and its output is taken across the resistor 10 and is fed if necessary via a filter network 11 to a demodulator 12.

In this example, the demodulator consists of a rectifying diode 13, and an integrating network comprising resistor 14 and capacitor 15. The characteristic of the filter network 11 is such that it has a passband characteristic extending from frequency F_1 to frequency F_2 so that it includes the two sidebands and excludes out-of-band noise and any external interference (such as may be due to ambient illumination or local artificial light). As the FET 9 is operative as a voltage follower, it provides just the necessary impedance buffering but gives no voltage gain so that the relatively high level of the diode output signal at the pump frequency is not increased. The action of the demodulator 12 is to remove the pump frequency F_P and to convert the two sidebands S_U and S_L to baseband as is represented diagramatically in Fig. 4. Thus Fig. 4 represents the wanted output consisting just of the amplitude modulation of the incident light.

The circuit described with reference to Fig. 1 is suitable for handling relatively low frequency signals, for example, in which the incoming optical power is amplitude modulated by a frequency shift keyed sub-carrier which represents the wanted data.

A higher frequency version of an electro-optical receiver in accordance with the invention is shown in Fig. 2 in which the same components bear the same reference numerals. The source of the pump signal produces much higher frequencies of the order of gigahertz and the pump signal is fed via a conventional narrow band filter circuit 30 to the diode 1. It is also fed to a demodulator which takes the form of a product detector 31 (balanced modulator) where the pump signal provides the carrier to facilitate demodulation. Thus, whereas the output of the transistor 9 contains the pump frequency. with the upper and lower sidebands as previously, the product detector 31 is operative to remove the carrier frequency and to convert the sidebands to baseband. A filter 32 connected to the output of the product detector acts as a baseband filter to remove any unwanted out-of-band frequency components.

The use of the parametric photodetector gives an output relationship which is very sensitive to low intensity light and whose output is linear with variations in incident light level. The signal to noise ratio can be very good indeed. As such, it is capable of providing a degree of performance which is very suitable for extracting data from amplitude modulated incident light.

CLAIMS

1. An electro-optical receiver including a photodetector arranged to receive incident light; means for applying a narrow band pump signal to said photo detector to cause parametric amplification of the incident light; a demodulator; and a wideband impedance buffer having a high input impedance adapted to pass to the demodulator a composite signal comprising the narrow band pump signal and signals representative of amplitude modulation of the incident light which are arranged as upper and lower sidebands with respect to the pump signal.

2. A receiver as claimed in claim 1 in which the photodetector is a photodiode.

3. A receiver as claimed in claim 1 or 2 and wherein the impedance buffer is a voltage follower circuit having a high input impedance.

4. A receiver as claimed in claim 3 and wherein a field effect transistor constitutes the voltage follower circuit.

5. A receiver as claimed in any of the preceding claims and wherein said narrow band pump signal is applied to said photodetector via a crystal filter.

6. A receiver as claimed in claim 5 and wherein the demodulator includes a rectifying diode.

7. A receiver as claimed in any of claims 1 to 4 and wherein the demodulator includes a product detector which utilises the pump signal to achieve demodulation.

8. An electro-optical receiver substantially as illustrated in and described with reference to Fig. 1 or 2 of the accompanying drawings.

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